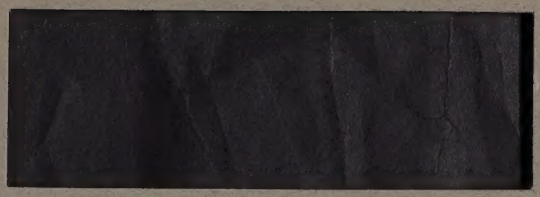


CAL LAB

2-7360

ELECTRONICS FOR COMMUNICATION • MEASUREMENT • CONTROL

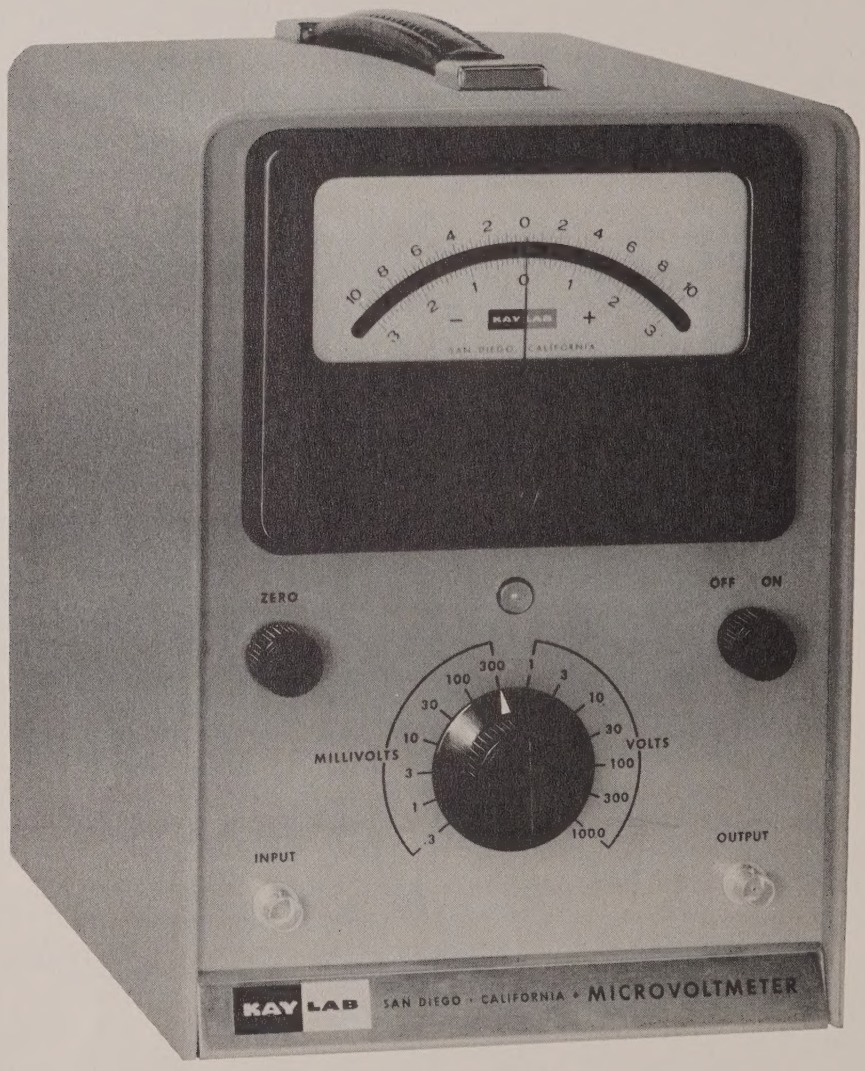
KAY LAB

5725 KEARNEY VILLA ROAD, SAN DIEGO 12, CALIFORNIA

MICROVOLTMETER
and
AMPLIFIER
MODEL 202B

TECHNICAL MANUAL

KAY LAB, 5725 Kearny Villa Road, San Diego 11, California



MODEL 202B MICROVOLTMETER

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PARTS LIST

SCHEMATIC DIAGRAM D8010000

KAY LAB will periodically issue change sheets to technical manuals. These may be found attached to the manual upon receipt or received through the mail.

Please make the necessary changes and record on this form. The originial change sheet may then be thrown away. The number of the last effective change at the time of issuance will be found at the botton of this form.

Changes subsequent to the date of issuance may be made. The number of the last effective change can be obtained by writing to the Graphic Arts Department, KAY LAB, 5725 Kearney Villa Road, San Diego 11, California.

MODEL NO. 202B

Change No.	Title	Initial

Number of last change applicable to this manual 1.

CHANGE NO. 1

MODEL 202B INSTRUCTION MANUAL

On 202B instruments with serial numbers 8055 and below, and on 202BR instruments with serial numbers 2011 and below , make the following changes to the parts list and schematic diagram, and dispose of this sheet.

(1) Change value of R57 from 4.7KΩ to 1.8KΩ

(2) Change value of R58 from 2.7 KΩ to 7KΩ.

(3) Change meter M1 from 150-0-150μa to 100-0-100μa.

12/14/56

SECTION 1

GENERAL

1.1 DESCRIPTION

The KAY LAB Model 202B is a combination DC microvoltmeter and amplifier. KAY LAB's proven chopper dircuitry provides high sensitivity with previously unobtainable drift-free stability and high input impedance. The instrument features an exceptionally wide range of measurements. Fourteen voltage ranges cover from 300 μv full scale to 1000 V full scale. The zero-center meter face indicates polarity on two mirrored scales which cover all ranges. The amplifier has a maximum gain of 70 db to an output connector on the front panel, providing for its use as a low-drift DC amplifier with high gain and very high input impedance.

1.2 APPLICATIONS

The Model 202B is an extremely useful instrument in electronic research and development, transistor production or circuit design, medical and biological research, geophysics, metallurgy, chemistry, or wherever accurate amplification or measurement of very small DC voltages is required. Because of the high input impedance, the instrument is useful as a recorder driver, where the recorder does not have the required high input impedance or sensitivity. The very wide voltage range of the instrument makes it most versatile as a general purpose DC vacuum tube voltmeter.

1.3 SPECIFICATIONS

Accuracy on all ranges	3% of full scale
Maximum gain as amplifier	70 db
Output voltage	1 V across 1000 Ω or more, full scale
Output impedance	Less than 5 Ω
Drift (after 15-min. warm-up)	15 μv equivalent input on the 300 μv range
Isolation resistance in probe	1 megohm
Power required	105-125 volts, 60 cycles, 30 watts (approximate)
Maximum internal noise (bounce)	± 10 μv equivalent input on the 300 μv range (The bounce occurs about a mean point which is readily discernible, and there is no possibility of its being "added" to the meter indication as an error. See Para. 3.1.1)
Input connector	UG-625/U, normally used for mating probe assembly
Output connector	UG-625/U
Dimensions	11" high, 7 1/2" wide, 11" deep
Net weight	14 pounds

VOLTAGE RANGE		INPUT IMPEDANCE
0/.3/1/3/10	mv	10 megohms
0/30	mv	30 megohms
0/100/300	mv	100 megohms
0/1/3/10/30	v	100 megohms
0/100/300/1000	v	100 megohms

Specifications subject to change without notice.

SECTION 2

CIRCUIT DESCRIPTION

2.1 FEEDBACK AMPLIFIERS

The KAY LAB Microvoltmeter and Amplifier, Model 202B, consists primarily of an amplifier using a large amount of feedback. The block diagram of Figure 2-1 indicates the general nature of the system.

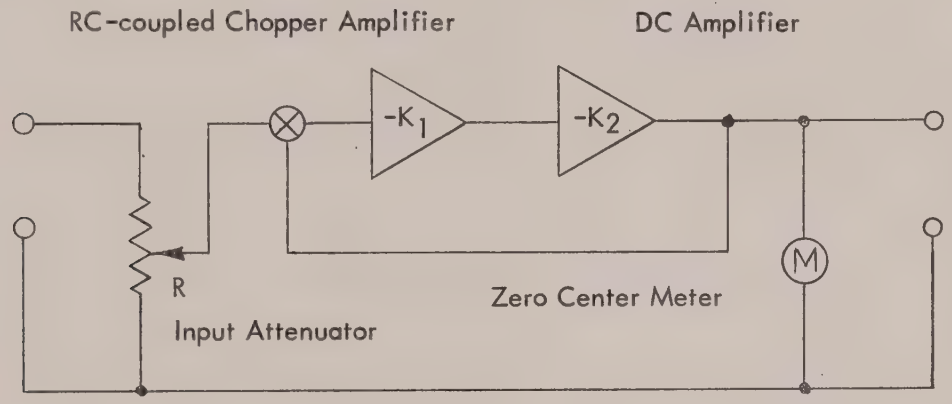


FIGURE 2-1

The forward gain of the system is approximately 116 db. For a maximum net gain of 70 db there is then 46 db of feedback. From the first through the third ranges the feedback is increased in steps of 10 db for a net gain of 50 db on the third and all higher ranges.

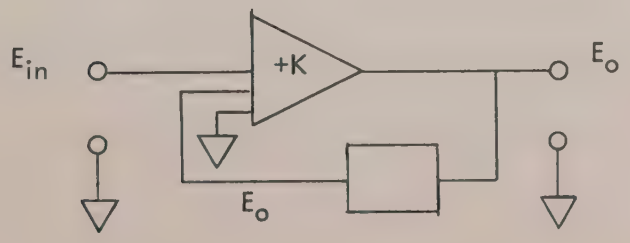
The purpose of the feedback is to stabilize the gain. It can be shown that where a large amount of feedback is used, the accuracy of the gain is nearly independent of tube and component variations.

For a positive amplifier (+K) as shown below, where the polarity of the feedback is such as to reduce gain (negative feedback), the net gain (A_n) with feedback is

$$A_n = \frac{E_o}{E_{in}} = \frac{E_o}{E'_{in} + \beta E_o} \qquad (1)$$

but

$$E_o = KE'_{in} \qquad (2)$$



E'in = net input

Ein = E'in + β Eo

Combining (1) and (2),

$$A_n = \frac{KE'_{in}}{E'_{in} + \beta KE'_{in}} = \frac{K}{1 + \beta K} \qquad (3)$$

It may be noted that this expression is generally given as

$$A_n = \frac{K}{1 - \beta K} \qquad (3a)$$

And β is assumed negative if the polarities are such that the feedback acts to reduce the gain. In either case, the result is the same. The gain reduction factor is termed the feedback factor. Where $\beta K \gg 1$, the feedback factor is

$$F = \beta K \qquad (4)$$

If the product of β K is much greater than 1, then the gain becomes nearly $\frac{1}{\beta}$.

The result is that the gain of the system is independent of all factors except the accuracy of the feedback network. Since the feedback network determining the feedback factor (β) can consist of precision resistors, the accuracy of the gain of the amplifier can be maintained at nearly the accuracy of the precision resistors.

2.2 THE AMPLIFIER SYSTEM

Since the KAY LAB Microvoltmeter and Amplifier must indicate the magnitude of extremely small DC signals, great amplification is necessary before the signal can be used to actuate a conventional DC microammeter movement. It was found that the gain could be rigidly fixed by the use of a large amount of feedback, thus adapting an electronic amplifier to measurement purposes. A conventional direct-coupled amplifier cannot be used however, because of the trouble encountered with drift and grid currents. If grid current is allowed to flow into the input system, an apparent input signal is developed which results in an erroneous output. In the conventional DC amplifier, drift may be caused by small changes in heater voltage or by normal tube aging resulting in changes in the emission characteristics of the tubes.

These difficulties may be overcome with the use of the chopper amplifier. The chopper amplifier reduces grid current flow in the input system to a negligible amount by use of an input coupling capacitor. Since the chopper amplifier amplifies an AC carrier signal which is proportional to the DC input, subsequent stages of amplification can be RC coupled, thus eliminating the effects of DC drift inherent in the direct-coupled system. Long term drift in the system due to thermal effects and circuit aging can be occasionally compensated for by use of a zero adjustment.

2.2.1 Chopper Amplifier

Figure 2-2 represents the basic chopper amplifier circuit used in the Model 202B.

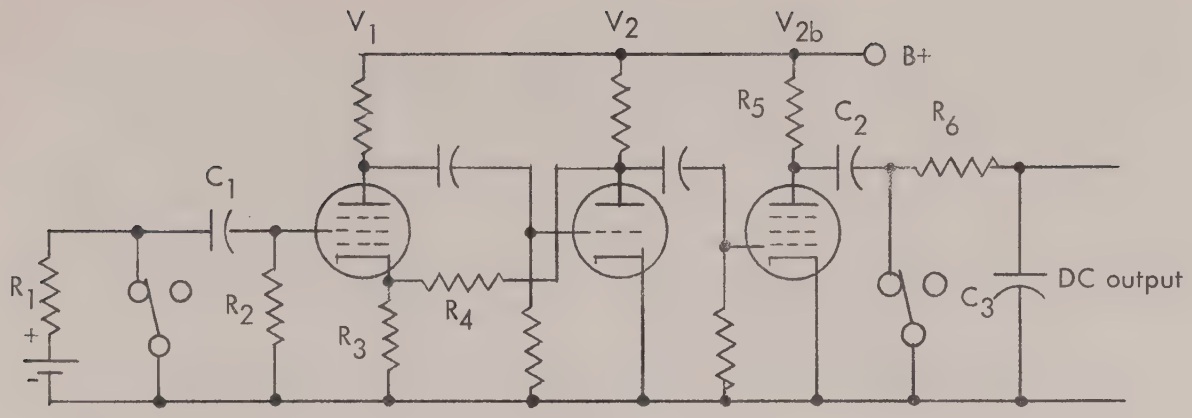


FIGURE 2-2

For simplicity, the feedback, plate decoupling, and other circuits that do not directly affect amplification and rectification are not included. The chopper amplifier in the Model 202B consists of three RC-coupled amplifier stages. The first stage is a special low-noise tube utilizing filtered DC filament voltage to maintain a low hum level. The second and third stages utilize a 6AW8 tube, and are triode and pentode respectively. V_1 operates with reduced filament voltage and consequently may suffer appreciable gain variations due to line voltage fluctuations within the rated range. Resistors R_3 and R_4 form a local feedback loop which, as shown in Para. 2.1, will cause the effect of gain variations in V_1 to be negligible. Thus overall system stability is maintained despite varying circuit conditions.

In Figure 2-2, the DC input signal to be amplified is represented schematically by a battery in series with a resistance, connected to provide a positive input signal. There are two possible positions of the chopper poles -- pole left and pole right. With the pole left, the input voltage is grounded by the input chopper and the input to the first stage is zero. With no input voltage, assume a quiescent plate voltage of 100 volts for the last stage. Then, with the output chopper pole left there is zero output because the junction of C_2 and R_6 is grounded, and C_2 is charged to the plate voltage (e_p) of 100 volts

When the input chopper pole goes right, an input signal of the polarity shown in Figure 2-2 is applied through C_1 to the grid of the first stage. This results in a decrease in the plate voltage of the first stage, an increase in the plate voltage of the second stage, and a decrease in the plate voltage of the third stage Assume that the plate voltage of the last stage drops to 90 volts. When the output chopper pole is thrown to the right, C_2 is no longer connected to ground. An output voltage is produced which is equal to the voltage that is now on the plate minus the voltage that C_2 was charged to just prior to the chopper pole being thrown right. If C_2 is charged to a nominal 100 volts and the plate voltage drops to 90 volts because of the positive input signal, the output is then ideally a square wave equal to -10 volts.

Although the input signal is positive with respect to ground this DC level is lost through capacitive coupling, and except for an initial transient condition, the plate voltage of the last stage will vary both above and below the quiescent DC value There-

fore, when the chopper pole goes left again, the plate voltage of the last stage will rise to plus 110 volts, but the output voltage will be zero because the junction of C2 and R6 is grounded during the period when the output chopper pole is to the left. The time constant R5C2 has very little effect on gain, and C2 does not discharge appreciably since R6, which is relatively large, is the only available discharge path. Of course, if R5C2 time constant is large compared to a half period at the chopper frequency, the rise time of the amplifier will be long. Ideally R5C2 will be short and R6C2 long compared to a half-period at the chopper frequency. The time constant R6C3 is long with respect to a half-period, but is determined by other considerations.

Consider a three-stage amplifier (Fig. 2-3) having unity gain which has been in operation for a period of time sufficient to reach a stable stage. Assume that the following conditions exist.

Chopper output perfectly symmetrical

$R1 \ll R2$

$R3 \ll R4$

$R5 \ll R6$

$R7 \ll R8$

$R2C1 \gg \frac{1}{2f}$

$R4C2 \gg \frac{1}{2f}$

$R6C3 \gg \frac{1}{2f}$

$R8C4 \gg \frac{1}{2f}$

$R8C5 \quad \frac{1}{2f}$

Let f = repetition frequency

All average plate voltages = 100 volts

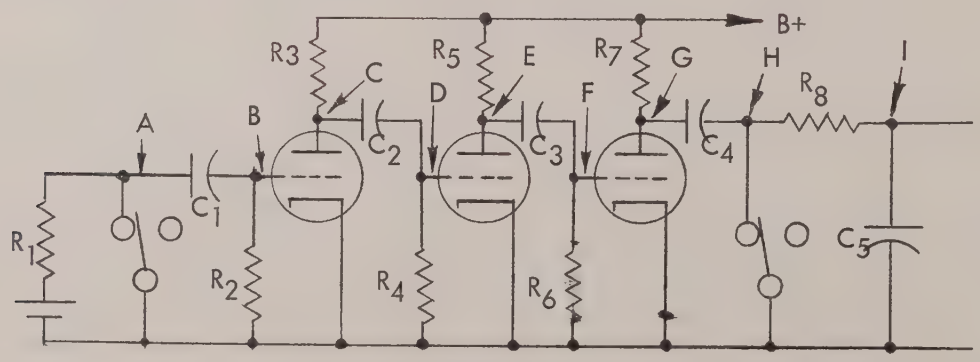


FIGURE 2-3a

These conditions establish good square wave response and maintenance of unity gain through the amplifier. The waveform is thus identical except for DC reference level and polarity at all points noted in Figure 2-3b.

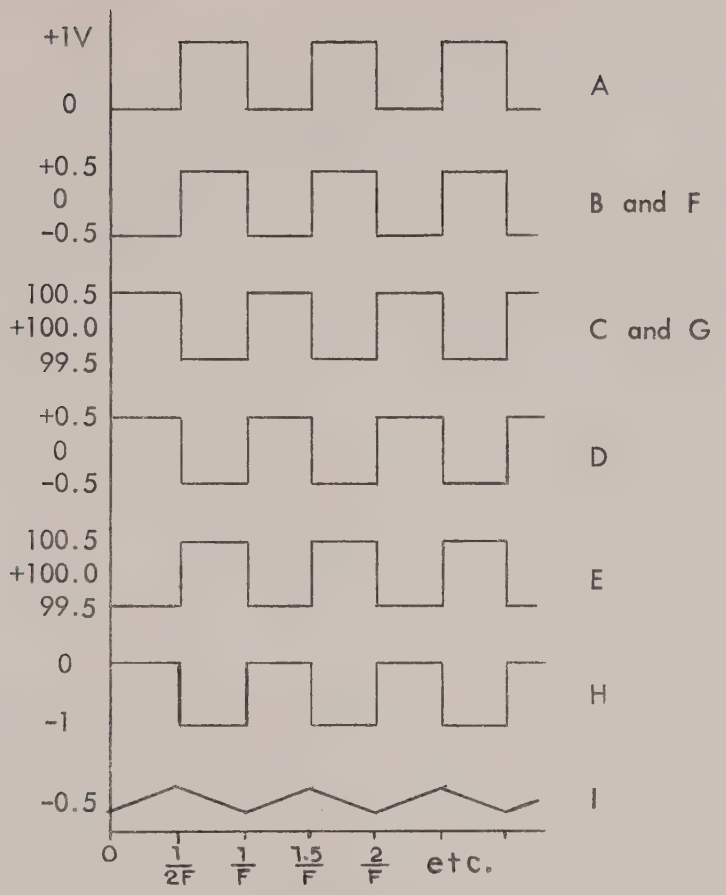


FIGURE 2-3b

At T = zero the chopper poles have just closed left. During the steady-state condition, C4 is charged to +100.5 volts, the plate voltage present on V3. At time T = 1/2f, V3 plate voltage drops to 99.5 volts. The difference, -1 volts, appears at the junction of R8C4. Thus the voltage across R8C5 alternates between zero volts and 1 volt. The average voltage across C5 is -.5 volt. Note that this amplifier, having unity AC gain, gives a DC to DC gain of 1/2, or a 6 db loss. This is the minimum loss possible in this amplifier, and in a practical three-stage chopper amplifier a DC to DC gain 10 to 12 db below the AC gain is to be expected.

The filter used in the 202B is more complex than the R8C5 network, and the output ripple is actually a sawtooth only a few millivolts in amplitude. As shown in Fig. 2-3, a phase reversal has occurred, giving negative output. However, the DC amplifier produces an additional phase reversal, making the over-all gain positive.

For the sake of clarity, a synchronously driven output chopper was used to describe operation of the chopper amplifier. However, because of certain design considerations, a driven diode system is used in the Model 202B. The method of utilizing a diode is similar to that of the output chopper. When the plates of the diodes swing positive they will conduct, acting as a short circuit across the output filter.

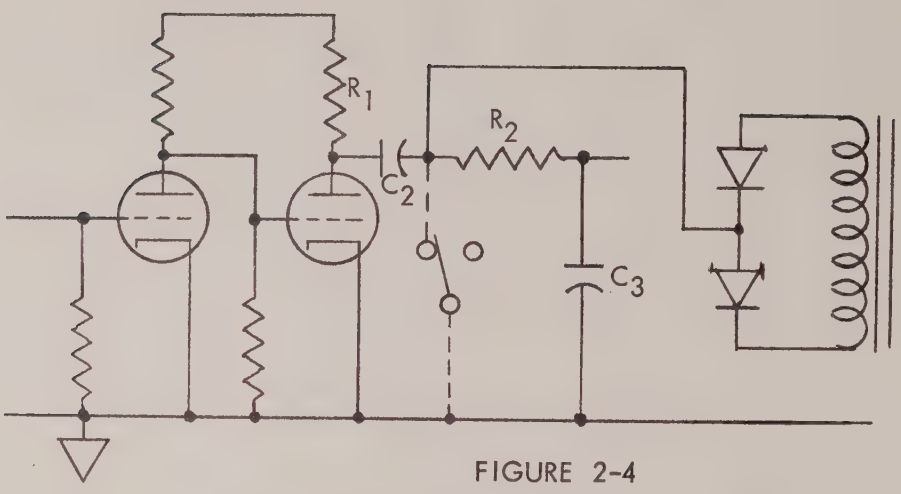


FIGURE 2-4
Diode circuit used to replace output chopper.

2.2.2 DC Amplifier

As has been stated, the purpose of the chopper amplifier is to reduce drift and other effects due to grid current, component and voltage changes, etc. However, after a number of chopper stages have brought the signal up to a level which can be handled by a direct-coupled amplifier, circuit economy demands that this type of amplifier be used.

The two-stage DC amplifier in the Model 202B consists of a triode amplifier and a cathode follower. A neon bulb, I1, is used in the interstage divider to minimize gain loss, since it has low dynamic impedance with a relatively large DC voltage drop. R54 sets the DC operating conditions in the amplifier, and the chopper amplifier is not required to furnish a steady bias voltage. The Thyrite resistor across the output and a plate resistor on the cathode follower limit the output voltage and current.

A capacitive feedback network is connected between the input and output of the DC amplifier. The function of the feedback network is to decrease the necessary size of the filter capacitor, to make system response time independent of DC amplifier gain variations, and to minimize the effects of internal disturbances in the DC amplifier.

2.2.3 The Feedback Circuit

In Section 2.1 the general expression for the gain of a feedback amplifier was developed. The application of this theory to a chopper amplifier will now be treated in detail. It will be shown that the gain of the chopper amplifier is $1/\beta$, as was the case for ordinary AC amplifiers.

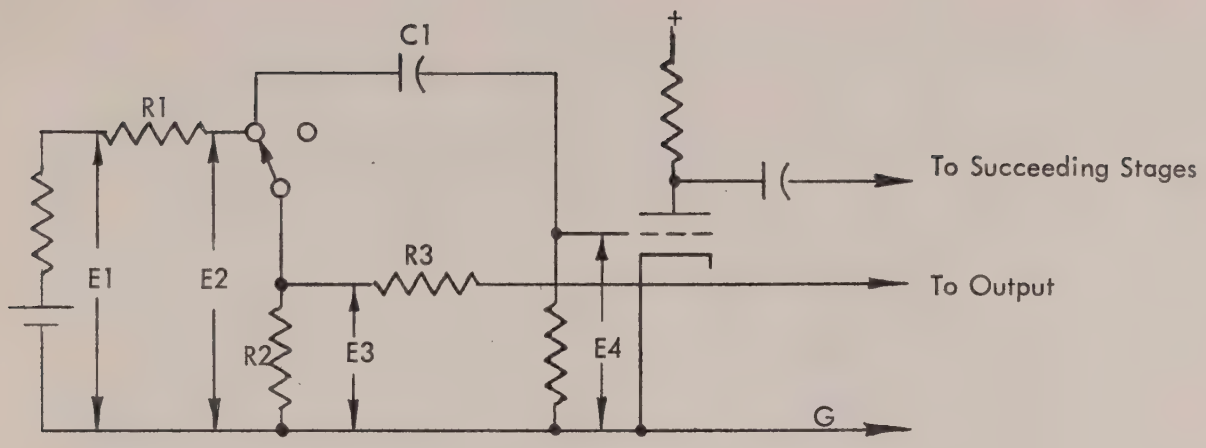


FIGURE 2-5

Let;

E1 be the DC signal to be measured, (5)

E3 be the DC signal fed back from the output and developed across R2, (6)

Eo be the DC output voltage, (7)

E2 then varies between E1 and E3 depending on the position of the chopper switch, (8)

E4 be the peak to peak value of the AC signal passed to the input of the amplifier. Since the DC portion is blocked by C1, E4 is the difference between E3 and E1, (9)

$E1 = E3 + E4$, (10)

β be the fraction of the output voltage fed back, and K be the gain of the amplifier without feedback, then

$$E3 = \beta Eo = \beta K E4 \quad (11)$$

The net gain of the system where $Eo = KE4$ is

$$An = \frac{Eo}{E1} = \frac{Eo}{(1 + \beta K)\, E4} = \frac{K}{1 + \beta K} \quad (12)$$

and if βK is much greater than 1

$$An \cong \frac{1}{\beta} = \frac{R2 + R3}{R2} \tag{13}$$

Thus it is seen that by making the gain sufficiently large, the gain of the system depends only upon the ratio of the resistors of the feedback network and can be maintained at the same accuracy as the accuracy of resistors R2 and R3 in Figure 2-5.

Note the effect of feedback on the apparent DC resistance seen by E1.

The current which flows without feedback is (switched closed),

$$i_{wo} = \frac{E1}{R} \tag{14}$$

The current which flows with feedback is (switched closed),

$$i_{wf} = \frac{E1 - E2}{R} = \frac{E1 - E3}{R} \tag{15}$$

Where Z_{wf} = apparent impedance with feedback, and Z_{wo} = impedance without feedback, the impedance is increased by the ratio

$$\frac{Z_{wf}}{Z_{wo}} = \frac{i_{wo}}{i_{wf}} = \frac{E_1}{E_1 - E_3} \tag{16}$$

Inserting (10) and (11) in (17),

$$\frac{Z_{wf}}{Z_{wo}} = \frac{E_1}{E_4} = \frac{E_3 + E_4}{E_4} = \frac{\beta K E_4 + E_4}{E_4} = K + 1 \tag{17}$$

If $\beta K \gg 1$,

$$\frac{Z_{wf}}{Z_{wo}} = \beta K \tag{18}$$

It may be shown that this feedback factor acts in the same manner to reduce the output impedance.

The factor K is approximately 5×10^6, and β may be as large as 3.3×10^{-3}. Thus, feedback factor βK may be as much as 16,000, and large input impedances are possible. Note, however, that the input impedance is not a fixed value as is the net gain, but depends on K, the forward gain of the system and hence is subject to the normal variations of an electronic amplifier without feedback. It is sufficient, however,

that the input impedance to the chopper be made much larger than the impedance of the attenuator which it shunts. When this is accomplished, the input to the instrument is then merely the resistance of the (nearly) unloaded attenuator. It is because this is actually achieved in practice that it is possible to place an accurate specification on input impedance to the instrument.

2.3 CIRCUIT DETAILS OF THE SCHEMATIC DIAGRAM

The schematic diagram of the instrument will be found in the appendix.

2.3.1 Input and Range Switching Circuit

The voltage to be measured is applied to the isolation probe which is used to minimize capacitive loading on the circuit being measured. The probe contains a 1 megohm resistor. The signal being measured is conducted through the isolation probe resistance and a shielded lead to the input attenuator.

The 14 position, three section, voltage range switch (S2a, b, c,) is shown in the upper left portion of the schematic diagram. On the first three ranges, the feedback of the system is varied by inserting feedback resistors R16 and R17. These resistors occupy the same position in the circuit as R_3 of Figure 2-5. On these ranges the gain of the amplifier is being varied rather than the input signal. This is advantageous with the extremely low energy input signals obtained on the lower ranges. On the 300 μv range, for example, the gain of the amplifier with feedback is found to be:

$$\frac{R_{15} + R_{16} + R_{17} + R_{26}}{R_{26}} = \frac{3694 + 7406 + 25930 + 10}{10} = 3704$$

This is a gain of approximately 70 db, including a 1 db divider loss on the lower ranges. On the 3 mv range, the gain is reduced to 370, or approximately 50 db.

Above the first three ranges, sections A and B of the voltage range switch function as a step attenuator on the input signal and the gain of the system remains constant as fixed by R15 and R26. The step attenuator is a 100 megohm divider comprised of R3 through R14, and R62. This attenuator makes use of the system shown in Figure 2-6.

On the .3, 1, 3, and 10 mv ranges, R62 and R5 through R14 form a voltage divider. The output is taken from the junction of R62 and R13 to ground for the first three ranges and between R12 and R13 for the 10 mv range. On the 30 mv range the divider consists of R62 and R4 through R14, with the output taken from the junction of R12 and R13. On the 100 mv range, all the resistance has been inserted in the circuit, and on the higher ranges only the take off point is varied. Except for the lower voltage ranges, the input resistance of the voltage divider network is 100 megohm. On the lower ranges, input impedance is sacrificed to obtain low noise operation and stable input impedance, which is more important on the lower ranges than high input impedance. When the signal is extremely small, the sensitivity is limited by thermal noise, no matter what circuit configuration is chosen.

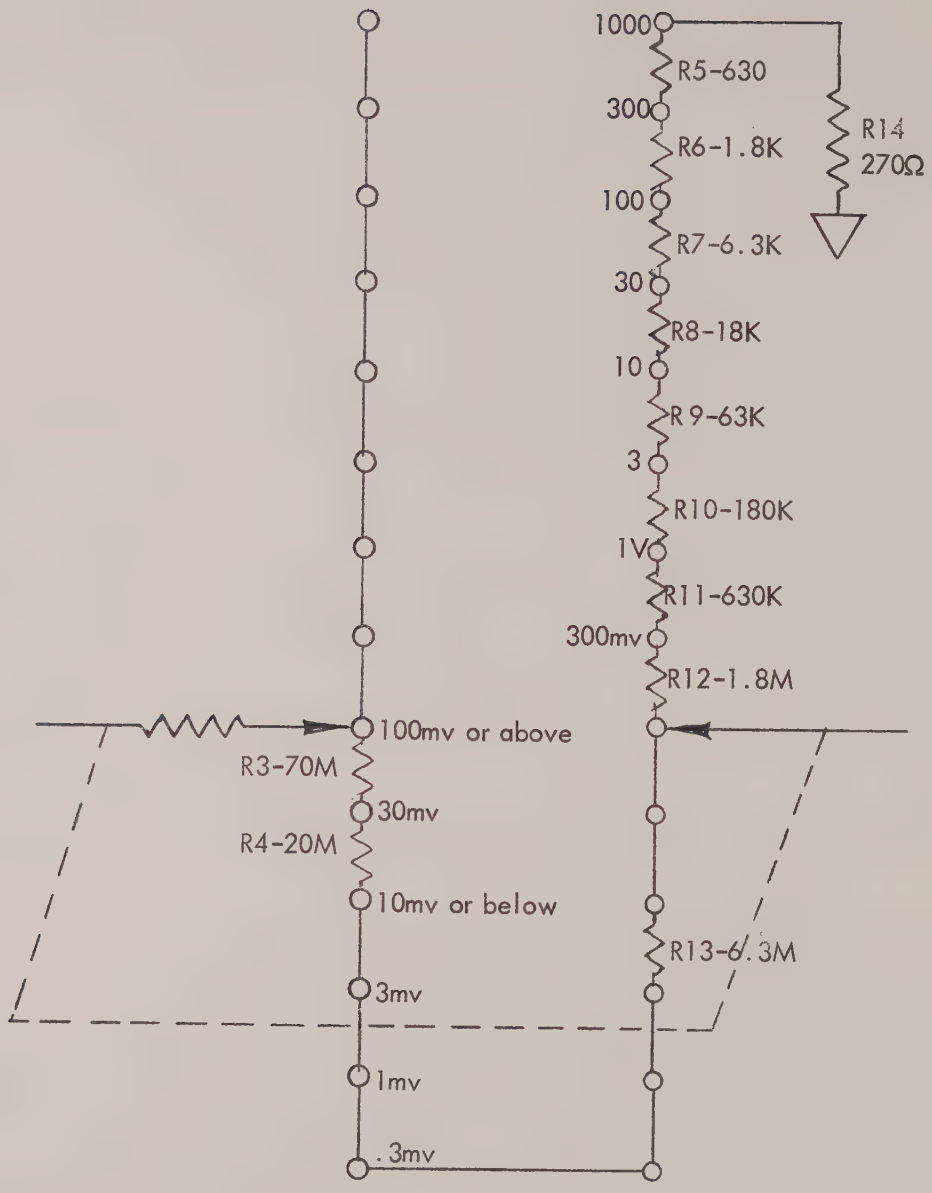


FIGURE 2-6

2.3.2 Chopper Amplifier

The chopper amplifier consists of chopper D1, capacitively-coupled amplifier tubes V1 and V2, and the chopper diodes.

The signal to be measured is fed from the attenuator section to the input filter. The purpose of this filter is to reduce any 60 cycle signal which might be superimposed on the DC signal to be measured. When such an AC signal is present, the signal indicated at the output will not be the average value of DC, due to synchronism between the chopper sequence and the AC ripple.

The input filter employs three RC sections to provide a sharp cut-off rate above a few cycles per second. The maximum high-frequency attenuation is limited by R_{19}, R_{21}, and R_{23}. This allows a fraction of a fast input signal to drive the input rapidly, which provides good 60 cycle rejection without a substantial increase in response time.

After filtering, the signal is fed to the chopper through R_{24}, which corresponds to R_1 of Fig. 2-5. The input chopper converts the DC signal to a proportional AC signal which is fed through two coupling networks, C_8 - R_{27}, and C_9-R_{29}. Use of these networks reduce the effects, at the input, of rapidly varying grid current in V_1. R_{36} provides feedback for gain stability, as does R_4 in Fig. 2-2.

Two RC coupling networks consists of C_{16} - R_{43}, and C_{18} - R_{44} are used in the output stage of the ACA. This arrangement has two purposes. The first is to reduce DC leakage due to the high plate potential. The leakage resistances in conjunction with the 10 megohm resistors result in a very large attenuation factor. In addition the low frequency cut-off is more rapid, reducing the effects of low-frequency line transients. There is no appreciable effect on demodulation, since the two capacitors are equivalent to one having 1/2 the capacitance, and the 10 megohm resistors constitute a DC load. There is a difference in charge characteristic, however. Charge due to signal is divided equally, while C_{16} holds most of the charge due to nominal plate voltage. In the last stage of the ACA the chopper diodes develop an output which is the difference between V_{2b} plate voltage, and the charge on C_{16} and C_{18}. This voltage is applied to the filter at the input of the DCA. The filter output is a DC signal with some ripple. This ripple is due principally to hum. The internal gain of the 202B is so high that only a very small input signal (E' in of section 2.1) is needed to set the output level, except during transient conditions. It is not possible to see this signal clearly in the presence of normal hum. Only a small change in the symmetry of the hum may be noticeable.

2.3.3 DC Amplifier and Output Circuit

The DCA utilizes a 6CG7 dual triode. One section is used as a conventional amplifier, the other as a cathode follower.

The meter is connected across the amplifier output in series with the proper multiplier and shunt resistance. R_{59}, a screwdriver adjustment, is provided for initial factory calibration.

SECTION 3

OPERATION

3.1 TURN-ON PROCEDURE

The instrument should be connected to a 117 volt, 60 cycle AC source and allowed a warm-up period of at least one minute. The zero control may then be adjusted. To do this, short the input, switch to the 300 μv range, and adjust the control on the front panel. The zero setting will then be correct for all ranges. It may be necessary to re-adjust the zero control after approximately fifteen minutes of operation. This control may be adjusted without shorting the input and without switching to the lower range. However, the adjustment obtained without these precautions may not hold precisely for all other ranges. The zero adjustment is necessary only to take care of long term changes in the circuits of the instrument. It is not necessary to readjust for zero each time the range switch is operated.

3.1.1 Noise Characteristics

The Model 202B, in common with all electronic instruments used for measurement, has an inherent noise level. This noise level is determined by factors such as input impedance, bandwidth, operating temperature, and, on line operated devices, internal pickup. The power level of this noise is so low that it does not affect instruments of average sensitivity. The Model 202B has a power sensitivity comparable to the finest galvanometer. Consequently it is possible to observe the input noise on the more sensitive ranges. This noise appears as a meter "bounce". For other than the lowest ranges, the net gain is reduced, and the "bounce" is reduced accordingly. Peak magnitude of bounce about a mean point on the Model 202B should be less than ±10 μv equivalent input. Typically, the bounce has a peak amplitude of ±3 μv. Line transients may cause an additional ±5 μv. This should be checked on the .3 mv range with the input probe shorted.

Normally, the probe that is provided with the instrument will provide the best performance. It is permissable to substitute a different probe for special applications. However, a 1 megohm, 5%, isolation resistor must still be used to retain accuracy. If cable capacity is not important, the isolation resistor may be installed inside the switch compartment. The probe cable provided with the instrument is Amphenol low-noise coaxial cable. Other types which are not low-noise may introduce transients when the cable is flexed.

3.2 PRECAUTIONS

The Model 202B will withstand severe overloading of the input. However, DO NOT exceed 1,500 VOLTS PEAK INPUT under any condition. Otherwise, maximum input should be restricted to 100 times the full scale rating being used; e.g., .1 volt on the 1 mv range or 100 volts on the 1 volt range. Even these amountswill produce a temporary zero shift and the meter will stay at full scale deflection for several seconds.

The normal precautions that must be observed when using any type of voltmeter should be observed with the Model 202B. When measuring unknown values of voltage, always start on the highest range and decrease the range setting to the appropriate range.

3.3 USE AS AMPLIFIER

If the instrument is to be used as an amplifier, the output signal is taken from the front panel connector. The minimum permissible load resistance is 1000 ohms.

SECTION 4

MAINTENANCE

4.1 PRECAUTIONS

When any measurements are made in the process of servicing, the instrument must be shielded. Use a sheet-metal shield in close proximity to the area shown in Fig. 4-1 and ground the shield to the chassis of the instrument. If the instrument is operated with the cover removed and without shielding, pickup from stray fields will overload the amplifier.

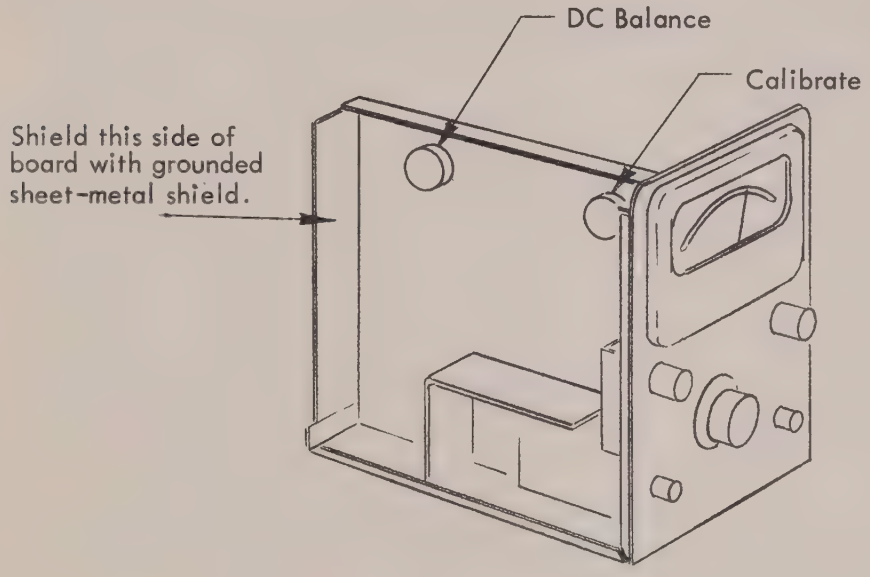


FIGURE 4-1

4.2 PREVENTIVE MAINTENANCE

The chopper and all tubes should be checked every 5000 hours of operation as a matter of routine. Electrolytic capacitors should be checked for leakage and correct capacity every two years. Note the use of a cardboard cover on the filter capacitor of the high voltage power supply. Since the case of this capacitor, C1, is 100 volts below ground, care must be taken to see that it is properly insulated to avoid shock hazard.

4.3 TROUBLE SHOOTING PROCEDURE

The trouble shooting procedure to be followed will depend on the nature of the trouble. If the instrument is completely dead and remains at zero on any voltage range, the trouble is probably in the power supply. After removing the instrument case, all power supply voltages may be checked from the indicated points on the printed circuit side of the etched circuit boards. If the voltages are not correct, the input voltage to the

power supply should be checked, and the tubes in the power supply should also be checked. If the power supply voltages are satisfactory and the meter is completely dead, the meter circuitry should be checked by measuring the output of the instrument at the output connector.

If the meter drifts very slowly to the right or left regardless of input signal, it is a good indication that the chopper amplifier is not operating. The driving voltage to the chopper should be checked. If the drive is correct, the chopper may be replaced and operation of the instrument rechecked.

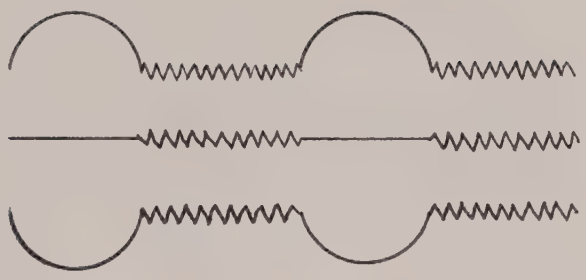
If the instrument fails to operate properly over a particular range, the corresponding components in the range switching circuit should be checked. For example, if the instrument fails to operate properly on any voltage range above 10 mv, it is probably that input attenuator resistor R4 is defective. Isolation of the probable source of trouble may be accomplished in a similar manner whenever faulty operation of the instrument is confined to a particular range or group of ranges.

If the instrument is producing sporadic changes at the output or is operating in a generally unsatisfactory manner, the first step will be to check all tubes. This may be accomplished with a tube checker capable of measuring transconductance, or by tube substitution. Some care must be used in selection of a chopper amplifier input tube. Generally, the Z729 produces excellent results in this circuit. The most obvious symptoms of defective Z729 chopper amplifier input tubes are either low gain or filament leakage. In the case of the former, sluggish performance will result. Filament leakage will cause 120 cycle ripple to appear at the ACA output (marked "SCA" on etched board). This hum usually results in a pronounced zero shift. If the tubes are satisfactory, the next step is a complete voltage check of the instrument.

In the Model 202B, the detector balance control is also the zero control. The diodes may be checked by rotating the zero control while observing the ACA output. The waveforms shown in Fig. 4-2 should be obtained.

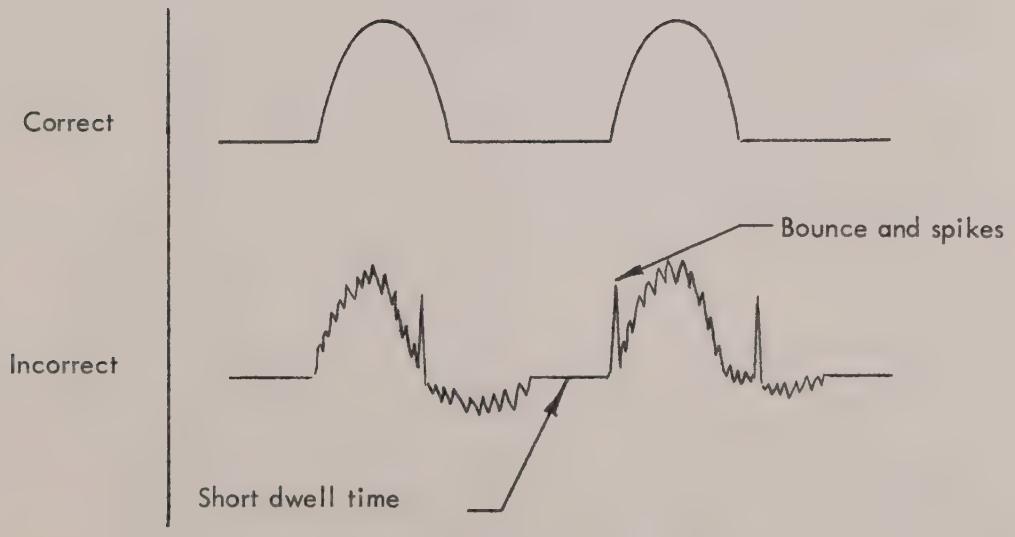
> (Note that the control is non-symmetrical, and also that the hum during the chopper contact open time may have different characteristics than shown in Fig. 4-2.)

Since the signal normally applied to the input chopper is not of sufficient amplitude to permit observation of the input chopper dwell time, an artificially large signal must be introduced. This may be accomplished by switching the instrument to the lowest range and connecting a 1.5 volt flashlight cell across the input terminals. The dwell time of the input chopper may then be observed by connecting the oscilloscope input probe to pin 9 of V1. To avoid a DC offset from the bias cell, use the oscilloscope on AC coupling. The waveform should reveal a period of zero voltage occuring approximately 55% of the total period. This occurs during the time that the chopper contacts are grounding the input. The grounded period is followed by a period when the chopper contacts are open. This period will generally indicate a large amount of hum which should be fairly consistent and free of excessive spikes, as shown in Fig. 4-3.



Chopper Diode Waveforms

FIGURE 4-2



Typical Chopper Waveforms

FIGURE 4-3

To check continuity of the input attenuator turn off the instrument and remove the chopper. Check resistance from the input probe to ground with an ohmmeter capable of measuring 100 megohms accurately. With the voltage switch on the 10 mv range the resistance is 10 megohms, on the 30 mv range, 30 megohms, and on the 100 mv range and above, 100 megohms. Any appreciable variation from these figures indicates attenuator trouble.

The balance control in the DCA is R54. It should be adjusted as follows:

Allow a warm-up period of at least 15-minutes. With the Model 202B set on the 3 mv range or higher and the probe shorted, connect a DC VTVM having 11 megohms or more input resistance from point "P" to ground and adjust R54 for zero volts. This is an average value, as some bounce will always be evident.

MODEL 202B

MICROVOLTMETER

PARTS LIST
Job 8010

RESISTORS		KAY LAB PART NO.
+R1A	*23Ω 5w Claro D8KS	5110002
+R1B	*500Ω 5w Claro D8KS	5110002
+R2A	*2.5K 5w Claro D8KS	5110001
+R2B	*5K 5w Claro D8KS	5110001
# R3	*70 meg 2w 1/2%	4806024
# R4	*20 meg 1w 1/2%	4806023
# R5	*630Ω 1/2w 1/2%	4705387
# R6	*1.8K 1/2w 1/2%	4705389
# R7	*6.3K 1/2w 1/2%	4706020
# R8	*18K 1/2w 1/2%	4705391
# R9	*63K 1/2w 1/2%	4705394
# R10	*180K 1/2w 1/2%	4705395
# R11	*630K 1/2w 1/2%	4705396
# R12	*1.8 meg 1/2w 1/2%	4706025
# R13	*6.3 meg 1w 1/2%	4806022
# R14	*270Ω 1/2w 1/2%	4705386
# R15	*3.694K 1/2w ±0.25%	5210001
# R16	7.406K 1/2w ±0.25%	5210001
# R17	25.93K 1/2w ±0.25%	5210001
	Cinema SW-3BE	
R18	390K 1/2w	4101352
R19	82K 1/2w	4101344
R20	560K 1/2w	4101354
R21	120K 1/2w	4101346
R22	680K 1/2w	4101355
R23	150K 1/2w	4101347
R24	1 meg 1/2w	4101357
R25	1K 1/2w	4101321
R26	*10Ω 1/2w .1%	
	Cinema SW-1AE	4707095
R27	3.3 meg 1/2w	4101363
R28	10K 1/2w	4101333
R29	15 meg 1/2w	4101371
R30	150Ω 1/2w	4101311
R31	390K 1/2w	4101352
R32	1.8 meg 1/2w	4101360
R33	47K 1/2w	4101341
R34	18K 1/2w	4101336
R35	100K 1/2w	4101345

RESISTORS		KAY LAB PART NO.
R36	330K 1/2w	4101351
R37	1.5 meg 1/2w	4101359
R38	1 meg 1/2w	4101357
R39	390K 1/2w	4101352
R40	3.3 meg 1/2w	4101363
R41	39K 1/2w	4101340
R42	82K 1w	4301574
R43	10 meg 1/2w	4101369
R44	10 meg 1/2w	4101369
R45	2.7 meg 1/2w	4101362
R46	270K 1/2w	4101350
R47	2.7 meg 1/2w	4101362
R48	39K 1/2w	4101340
R49	39K 1w	4301570
R50	470Ω 1/2w	4101317
R51	39K 1/2w	4101340
R52	50K 2w A-B Pot	5010054-7
R53	56K 1w	4301572
R54	100K 2w A-B Pot	5010015-9
R55	390K 1/2w	4101352
R56	33K 1w	4301569
R57	*4.7K 1/2w 1/2%	4710002
R58	*2.7K 1/2w 1%	4710001
R59	1K 2w A-B Pot	5010013-9
+R60	82Ω 1/2w	4101308
+R61	120Ω 1/2w	0101310
≠R62	*1 meg 1/3w 5%	4207343
+R63	270Ω 1/2w	4101314
+R64	270Ω 1/2w	4101314
R65	18K 1w	4307343

* Recommended Spare

\+ Power Supply

\# Attenuator

≠ Probe Assembly

MODEL 202B

MICROVOLTMETER

PARTS LIST
Job 8010

CAPACITORS		KAY LAB PART NO.
+C1A/B	*40/40 µf 500V	051006
+C2A/B	*1000/1000 µf 15V	051007
C3A/B	*80/40µf 150V	051005
#C4	100 µµf 1500V Mica Cap	707785
C5	.02 µf 200V Mylar 620	607251
C6	.02 µf 200V Mylar 620	607251
C7	.01 µf Ceramic Disc	401056
C8	.01 µf Ceramic Disc	401056
C9	.005 µf Ceramic Disc	401039
C10	100 µµf Ceramic Disc	401022
C11	.25 µf 200V Mylar 620	606278
C12	.002 µf Ceramic Disc	401048
C13	.01 µf Ceramic Disc	401056
C14	.1 µf 200V Mylar 620	606443
C15	.25 µf 200V Mylar 620	610001
C16	.1 µf 400V Mylar 620	607317
C17	.002 µf Ceramic Disc	401048
C18	.1 µf 200V Mylar 620	606443
C19	.05 µf 200V Mylar 620	607318
C20	.25 µf 200V Mylar 620	610001
C21	.001 µf Ceramic Disc	401046
C22	100 µµf Ceramic Disc	401022
C23	.01 µf 200V Mylar 620	606740
C24	.01 µf 200V Mylar 620	606740
+C25	.01 µf Ceramic Disc	401056
+C26	.01 µf Ceramic Disc	401056
C27	100 µµf Ceramic Disc	401022
C28	.02 µf 200V Mylar 620	607251

MISCELLANEOUS		KAY LAB PART NO.
BT1	Bias Cell RM625T	1804158
CR1	*Diode 3U1	3506774
CR2	Diode 3U1	3506774
+CR3	*Diode IN91	3506751
+CR4	Diode IN91	3506751
D1	Brown Chopper SS-8899KC	6306855
F1	Fuse .3 amp. SloBlo	1710027
I1	Neon Lamp NE 2	1704151
I2	Pilot Lamp #47	1704149
L1	25 µh Choke Coil	2306773
M1	Meter 150-0-150 µa	3010001
RT1	*Thyrite 432 BNR-18	4904225
S1	SPST Rotary Switch 250V - 3A #570	6206247
#S2	14 Pos. 3 Pole Rotary Oak 77016-L3	6210004
T1	Transformer 8346	6507187

TUBES

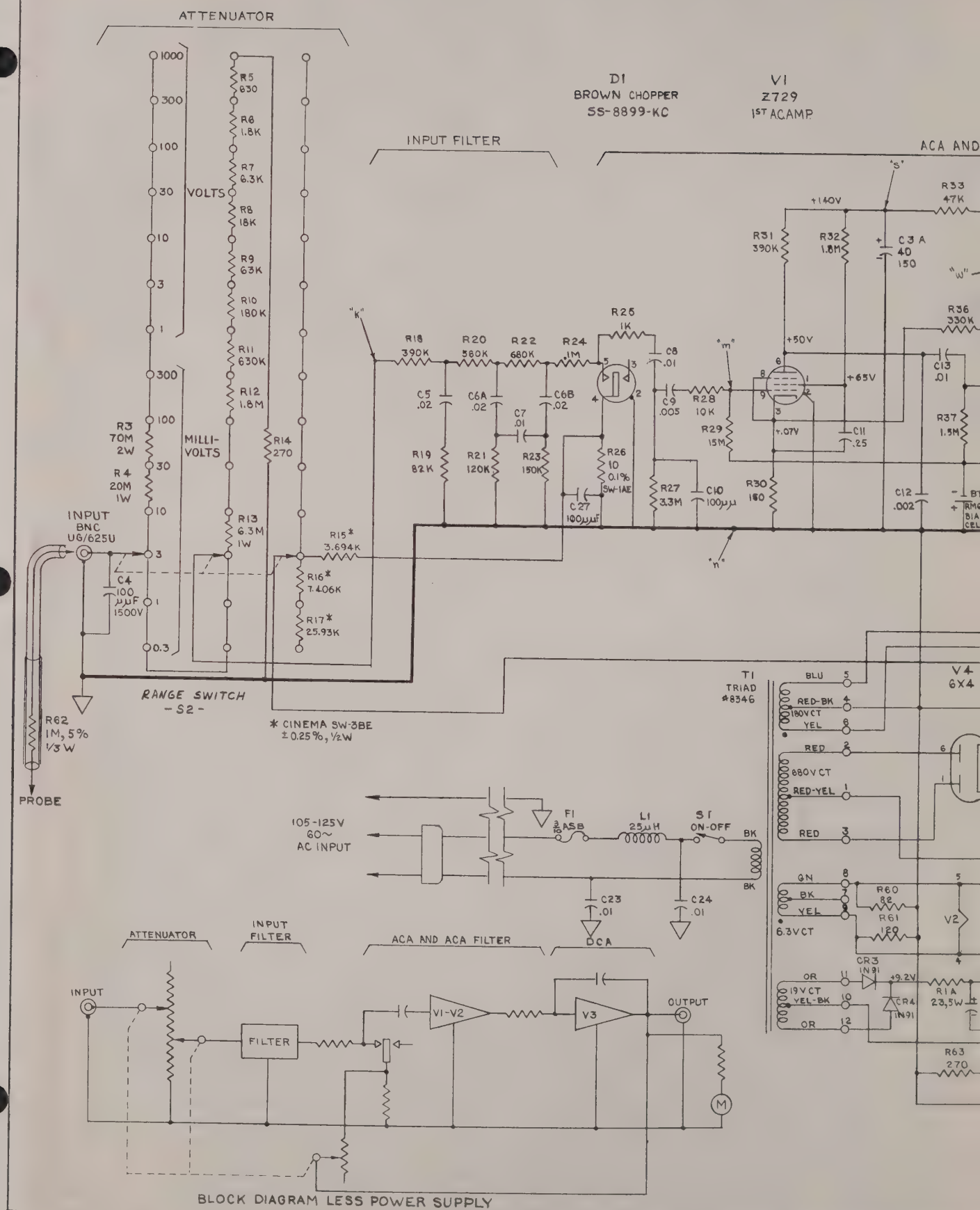
V1	*Z729	7005715
V2	*6AW8	7007419
V3	*6CG7	7006354
V4	*6X4	7002786
V5	*OA2	7302792
V6	*OB2	7302794

* Recommended Spare

\+ Power Supply

\# Attenuator

10-10-56



BLOCK DIAGRAM LESS POWER SUPPLY

APPROV.	LET	CHANGE	DATE	ORDER
	A	INCORP. E.O. 886, SCHEM. ONLY	10/12/56	E.O. 886
	B	R57 WAS 1.8K, ½%; R58 WAS 7K; M1 WAS 100-0-100 μA	10/19/56	E.O. 937
	C	F1 WAS 1A. SB; ADDED TP AT "P"	11-23-56	E.O. 987

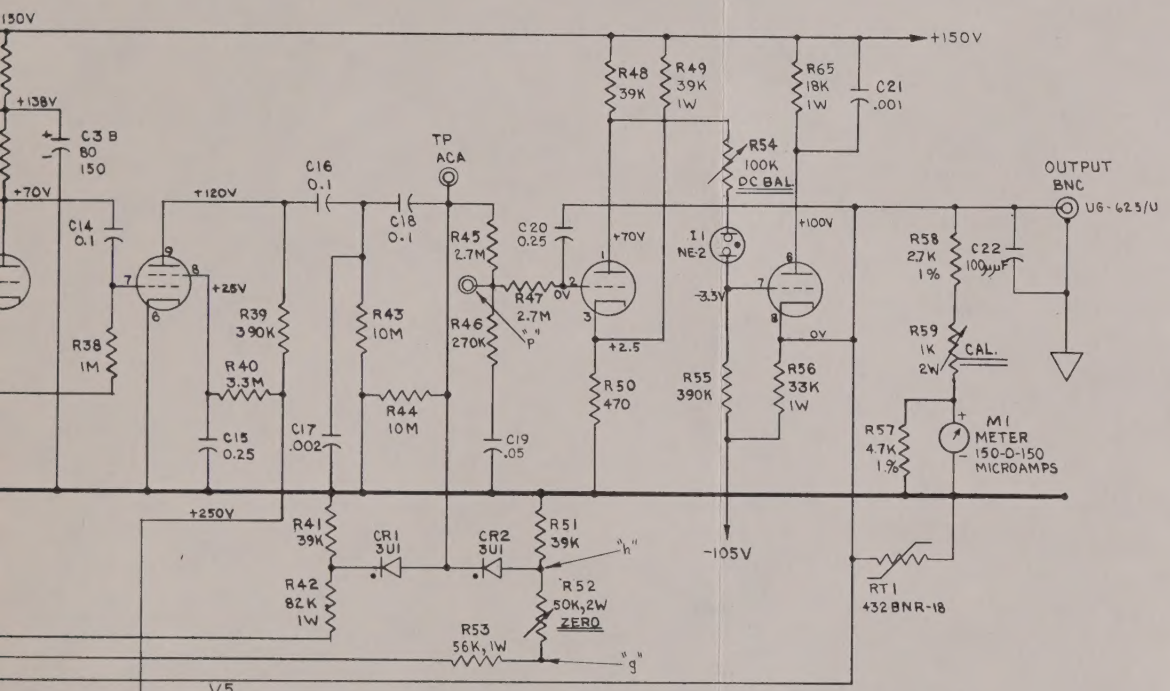
V2A
6AW8
AC AMP.

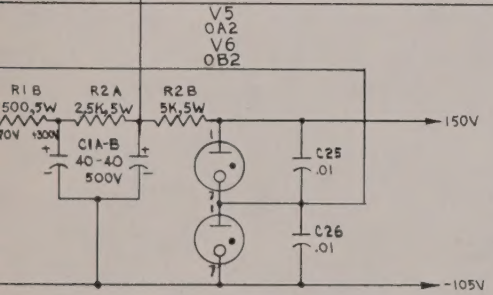
V2B
½ 6AW8
3RD A.C. AMP.

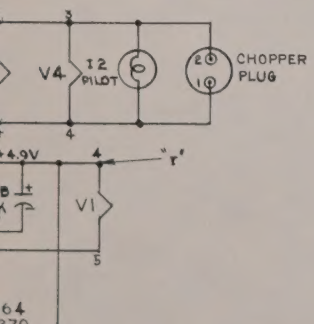
V3A
½ 6CG7
D.C. AMP.

V3B
½ 6CG7
CATHODE
FOLLOWER
DCA

A FILTER







NOTES

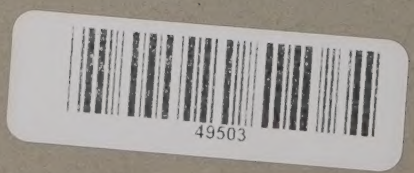
1. VOLTAGES SHOWN ARE APPROXIMATE FOR NORMAL OPERATION AS MEASURED WITH A VTVM OF 100 M INPUT RESISTANCE
2. LETTERS g, h, k, m, n, p, r, s, w REFER TO POINTS IN CIRCUIT WHICH ARE IDENTIFIED ON ETCHED BOARDS.

ALL RESISTORS ½ WATT,
ALL RESISTANCES IN OHMS,
ALL CAPACITANCES IN MICROFARADS
UNLESS OTHERWISE SPECIFIED.

MODEL 202B
DC MICROVOLTMETER
SCHEMATIC

KAY LAB
9525 KEARNEY VILLA ROAD SAN DIEGO 12, CALIF.

DATE 7/30/56
DRAWN BY
APPROVAL
DRAWING NO. D8010000
JOB NO. 8010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